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ICT implants in the human body : a review

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Introduction

Present day uses such as heart pacemakers, cochlear implants and neurostimulators are not the focus of this paper. Rather, attention is given to implants that use computer technology either for control/surveillance or enhancement purposes.

Apart from one example (the subdermal RFID device, Verichip™, see below), all of these ICT implantations are active implantable devices for "functional electrical stimulation". They partially replace the neural functions of the body by means of electrodes that establish a direct contact to nerves.

http://www.medics-network.com/download/schneidersteiglitz_jf04.pdf

"Over the last 50 years, we have seen evolution of pacemaker technologies, as an accepted form of intrusion into human body." This is confirmed by the recent U.S. Food and Drug Administration approval of implantable ID chips in humans, for security, financial and personal identification or safety applications.

Besides medical purposes, *"for [healthy] beneficiaries, implant technologies involve possibly some future advantages, like rapid math, memory capacity or communication by thought."*

[quoted from http://www.unido.org/file-storage/download/?file_id=10499]

Categorisation of Implantable Devices

Implantable devices can be categorised as **medical** or **non-medical** devices, both either **passive** or **active** devices.

✚ Implantable medical devices

Most passive implants are structural devices such as artificial joints, vascular grafts and artificial valves. On the other hand, active implantable devices require power to replace or augment an organ's function or to treat an associated disease.

The **Council Directive 90/385/EEC on active implantable medical devices** gives the following definition: "active implantable medical device" means any active medical device which is intended to be totally or partially introduced, surgically or medically, into the human body or by medical intervention into a natural orifice, and which is intended to remain after the procedure;

The "device" definition within the meaning of Directive 90/385/EEC relates to a product intended by the manufacturer for a medical purpose "whether used alone or in combination, together with any accessories or software for its proper functioning". The medical purpose may be achieved either by a "stand alone device" or as a result of several devices acting each in combination with the other as part of a system.

✚ Implantable non-medical devices

An example of a passive device is the radio frequency identification (RFID) device. Active devices may use electrical impulses to interact with the human's nervous system.

PART I: Implantable devices already available on the market

This first section contains information about implants in the human body that are available in commercial form and have been researched, in some cases, for decades.

1. Current active medical devices

- ✚ Cardiovascular pacers for patients with conduction disorders or heart failure
- ✚ Cochlear and brainstem implants for patients with hearing disorders
- ✚ Implantable programmable drug delivery pumps
 - ✓ **Intrathecal administration of Baclofen** for patients with Multiple Sclerosis with severe spasticity
 - ✓ **Insulin pump** for Diabetes
 - ✓ **Neuroleptic /antipsychotic drugs**, the so-called "psychiatric implants"

✚ Implantable Neurostimulation Devices

- ✓ **Spinal cord stimulation** for chronic pain management
- ✓ **Sacral nerve stimulation** for control of urinary incontinence
- ✓ **Vagus nerve stimulation (VNS)** for **seizure control in epilepsy** and **mood control in severe depression cases**: the small generator and lead are surgically attached to the rib cage, with the wires travelling under the skin up to the neck and wrapping around the left Vagus nerve. From there the generator sends electrical signals via the Vagus nerve to the brain.

The VNS therapy system, developed by Cyberonics, Texas, has been widely used to reduce epileptic seizures since 1997 in the US.

In July 2004, the US Food and Drug Administration approved the implantable VNS therapy as a treatment for untreatable chronic depression.

According to studies presented by Cyberonics, "*stimulation of the left Vagus nerve produces widespread and bilateral effects in the parts of the brain implicated in epilepsy, depression, anxiety and memory.*"

<http://usmedicine.com/article.cfm?articleID=912&issueID=64>

(Accessed on 29 November 2004)

✚ Deep brain (thalamic) stimulation

- ✓ for tremor control in patients with **Parkinson's disease**: "On April 1998, a breakthrough therapy (Activa® Therapy, Medtronic, Inc; <http://www.medtronic.com>) combating the symptoms of disabling Parkinson's disease, obtained the CE mark and was released on the European Union market. This technology involves mild electrical

stimulation of the *globus pallidus* or the subthalamic regions of the brain to control the major symptoms of Parkinson's – stiffness of limbs and joints, slowness or absence of movement, impaired balance and co-ordination, in addition to the characteristic involuntary rhythmic shaking (tremor). More than one million people across Europe are estimated to suffer from Parkinson's disease. Patients whose disease is not controlled by medications have difficulty in performing the basic tasks of daily life."

The implantable system includes a neurostimulator connected to a lead with four tiny electrodes near the tip. "The neurostimulator, which contains a battery and a microelectronic circuitry, is placed under the skin near the collarbone and provides the mild electrical stimulation that is carried through the lead to the electrodes implanted deep in the brain.

The level of stimulation can be adjusted externally to meet individual patient needs.

The therapy is completely reversible. The estimated longevity of the implanted battery is three to five years, with 16 hours of use per day."

<http://www.eucomed.be/docs/MT-IP-parkinson%60s%20disease.pdf> (Accessed on 25 October 25 2004)

- ✓ for **essential tremor**: Patients with essential tremor have no symptom other than tremor, which may occur in their hands, head, legs, trunk or voice. As for patients with Parkinson's disease, they can be helped thanks to the deep brain stimulation therapy.

2. Current identification and location devices

✚ Introduction: microchip devices might have three embodiments

- ✓ **"Read-Only**: this is the simplest form of devices that have a read-only character, similar to that now used for identification of animals. Even this most basic form would have numerous applications, for example, to identify Alzheimer's patients, children and the unconscious. A broader use would be as a sort of national identification card, based upon the identifying number carried on the microchip."
- ✓ **"Read-Write**: this type of microchip would be capable of carrying a set of information which could be expanded as necessary. It allows the storage of data and is programmable at distance. For example, when the microchip carries a person's medical history and the history evolves, the subsequent information could also be added to the microchip without the necessity of removing the implanted chip. It could also facilitate and record financial transactions. The third important set of information that a read-write microchip could carry would be criminal records."

At present, the Verichip™ (see below), for example, includes a memory that holds 128 characters only. Larger microchips, and highly specialized and more sophisticated ones, are underway.

- ✓ **“Read-Write with tracking capabilities:** in addition to the read-write capabilities described above, a device can also emit a radio signal which could be tracked. Applications would again be numerous as evidenced by the less advanced technologies already in existence. Such a device needs a power source, that has to be miniaturized before being implantable. If a microchip implant had tracking capabilities, it would be superior to the currently available electronic tether because it would not require the telephone as an adjunct. With a microchip implant, constant monitoring would be possible. If each chip emitted a signal of a unique identifying frequency, implanted individuals could be tracked by simply dialling up the correct signal. Because the receiver is mobile, the tagged individual can be tracked anywhere. “

www.fplc.edu/risk/vol8/fall/ramesh.htm

(Accessed on 24 October 24 2004)

✚ RFID devices

Millions of Radio Frequency Identification Device (RFID) tags have been sold since the early 1980s. They are used for livestock, pet, laboratory animals, and endangered-species identification.

This technology contains no chemical or battery. The chip never runs down and has a life expectancy of 20 years.

How it works.

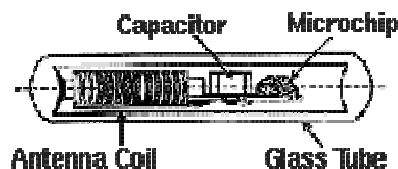
The chip is an ID tag which is inert/passive (not independently powered). When radio-frequency energy passes from a scanner, it energizes the chip, which then emits a radio-frequency signal transmitting the chip's information to the reader, and which in turn links with a database.

How the information is used is determined by the administrators of the security systems and databases.

✚ VeriChip™ or the “human bar coding”

VeriChip™ is a subdermal RFID device, about the size of a grain of rice, commercialized by Applied Digital Solutions (ADS), one US-based company.

What is its composition?



“The RFID implant consists of a microchip, an antenna coil and a capacitor all enclosed within a sealed glass tube. An anti-migration cap surrounds the glass tube to inhibit movement of the RFID within the tissue where the device is placed.”

www.angelfire.com/hi2/gracebelievers/microchip_implants_apr2003.pdf

The idea for employing the tags to identify humans came after the horror of the 11 September 2001 attacks on the World Trade Centre in New York.

FDA appears to have carried out a preliminary risk assessment (using the company's safety testing data) in giving marketing approval for this device (<http://www.sec.gov/Archives/edgar/data/924642/000106880004000587/ex99p2.txt>).

The letter of approval lists all the identified hazards and indicates that there is "reasonable assurance of the safety" of the device for the intended use (as a subcutaneous RFID). The potential risks to health identified by FDA include "adverse tissue reaction, migration of implanted transponder, failure of implanted transponder, electromagnetic interference, electrical hazards, magnetic resonance imaging (MRI) incompatibility and needle stick."

Current application of the VeriChip™

According to ADS, VeriChip™ provides security for:

- ✓ Medical records and healthcare information (blood type, potential allergies and medical history)
- ✓ Personal information/identity
- ✓ Financial information (secondary verification)

Besides these areas, the extended applications include public transportation security, access to sensitive buildings or installations and tracking down of people on parole, ex-convicts, criminals, etc.

Right now, a person has to stand within a few feet of a scanner for the tag to "wake up". Thus, the tags can be used to follow someone's steps only when they are near scanners. Consequently, the VeriChip™ is not for the moment an implantable GPS device (see below).

At present, the implantation is purely voluntary.

After Mexico, Colombia, Argentina, Brazil, Chilli, Paraguay and Uruguay, and following a broad advertisement tour in North America, the Verichip™ is now arriving in Europe as well.

1. In **South America**, faced with the huge problem of kidnappings, the VeriChip™ is being marketed mainly to identify kidnapped children or adults.
2. **Italy**: On April 2004, the Ministry of Health and the Instituto Nazionale Lazzaro Spallanzani Hospital started a study to evaluate the VeriMed™ system's impact on improving the quality of care provided to patients
3. **England**: Surge IT Solutions intends to use the VeriChip™ technology for secure building access for government installations, educational facilities, and various identification applications.

3. Current commodity devices

Credit card implant

In the Baja Beach Club (in **Spain** and **The Netherlands**), people use the VeriChip™ much like a smartcard to speed drink orders and payment. <http://www.baja.nl>. (Accessed on 24 October 2004).

✚ Remote-control Orgasm Implant

For the electronic orgasm device to work, a physician would implant electrodes into the spine and a small signal generator in the skin under the buttocks. A patient would then control the sensation with a handheld remote control.

<http://www.newscientist.com/news/news.jsp?id=ns9999397>

(Accessed on 8 December 2004)

PART II: Implantable devices UNDER DEVELOPMENT

4. Future active medical devices

✚ MEMS (Micro Electro-Mechanical System)

The micro-electro mechanical systems device (MEMS) is an implantable micro-sensor that can send data to a hand-held receiver outside the body, alerting doctors to a potential medical crisis, without using any wires or batteries.

✚ Brain prosthesis

- ✓ **artificial hippocampus:** an implantable brain chip that could restore or enhance memory.

The hippocampus plays a key role in the laying down of memories. Unlike devices such as cochlear implants, which merely stimulate brain activity, this chip implant will perform the same processes as the damaged part of the brain it is replacing. It will be a way to help people who have suffered brain damage due to stroke, epilepsy or Alzheimer's disease.

There are several research teams in Europe and the US that are currently working on so-called neural-silicon hybrid chips.

Theodore Berger at the University of Southern California in Los Angeles is emulating the neurons' behaviour on slices of rat brain bombarded by electrical input. Now, its silicon microcircuit is about to be tested in live rats.

Berger and his team have taken nearly ten years to develop their current chip models of 100 neurons. However it will need at least a 10,000-neuron chip model for implantation in a primate hippocampus. <http://www.newscientist.com/news/news.jsp?id=ns99993488>

- ✓ **Cortical implant** for the blind:

Electrodes implanted in the visually responsive areas of the brain would supply vision to the profoundly blind. Cortical implants require brain surgery and the pneumatic insertion of electrodes into the brain to penetrate the visual cortex and produce highly localized stimulation. <http://www.spectrum.ieee.org/publicaccess/9605teaser/9605vis6.html>

- ✚ Ocular implant : implantation of an electrode array on the retina; retinal implants avoid brain surgery and link a camera in eyeglass frames via laser diodes to a healthy optic nerve and nerves to the retina

- ✚ Brain-computer interfaces or direct brain control

The technologies involved here are communication technologies; they take information from the brain and **externalize** it.

There are **internalizing** technologies (cochlear or optic-nerve implants) whose purpose is to take information from the outside and provide individual access to it. These two technologies will eventually come together to form **interactive** technologies which would allow input-output interactions.

A US-based company called Cyberkinetics, specialized in neurotechnologies wiring computers to human brain, has received Food and Drug Administration approval in April 2004 for a clinical trial of the BrainGate™ Neural Interface System. If successful, this four-square-millimeter chip could allow paralyzed people to send computer commands by thought.

How does the BrainGate™ work?

"The neural signals are interpreted by the System and a cursor is shown to the user on a computer screen that provides an alternate "BrainGate pathway". Then, the user can use that cursor to control the computer, just as a mouse is used."

<http://www.cyberkineticsinc.com>

Although human studies show the feasibility of using brain signals to command and control external devices, the researchers emphasize that many years of development and clinical testing will be required before such devices - including "neuroprosthetic" limbs for paralyzed people, become available.

At the same time, because of what most people mean by brain-computer interfaces (BCI), there is also a lot of work done to create non-invasive BCIs.

Neurofeedback

Neurofeedback is a learning procedure – a kind of exercise for the brain - that is already widely used for conditions such as depression, epilepsy, sleep disorders and many others.

Several companies are now looking to find a way to increase mental well being and mental prowess using brain-computer interface **and** neurofeedback techniques.

This process involves connecting electrical impulses from the user's brain to the computer and back again, creating a feedback loop between the computer and the user. Neurofeedback allows the computer to interact with the user through electrical impulses.

Such devices induce brain states that are similar to those seen on an EEG when one is learning or concentrating on a task. By artificially inducing these brain states researchers hope to provide a means of personal control of one's own mood and emotional state.

5. Future personal tracking devices

Subdermal GPS Personal Location Device

Such a device would allow an individual with a scanner to pinpoint someone's position on the globe.

In May 2003, Applied Digital Solutions (ADS) claimed that a prototype implantable GPS tracking device had been successfully tested. However, technical experts are questioning whether the system could really work. The disc-shaped "personal location device"

measures 6.35 centimetres in diameter and 1.27 centimetres in depth - roughly the same size as a pace-maker. <http://www.adsx.com/news/2003/051303.html>

Currently it consists of an antenna to receive signals from the satellite constellation that comprises the Global Positioning System and an induction-based power-recharging system. The latter should make it possible to recharge the device's batteries from outside the user's body. Eventually the device will need to connect to a cell phone network if it is to relay the satellite-determined position of its host to another person.

ADS says it should be possible to shrink the overall size of the device by at least half.

This GPS monitoring could be used for several purposes, such as for example,

- in case of Medical emergencies
 - ✓ Heart attack
 - ✓ Epilepsy
 - ✓ Diabetes
- for identification and location purposes
 - ✓ People in high risk occupations
 - ✓ Children
 - ✓ Stalkers
 - ✓ Suspected terrorists.

In England, Kevin Warwick, a professor at Reading University, is also developing an implantable GPS microchip. <http://www.kevinwarwick.com>

6. Future enhancement or commodity devices

According to Ellen McGee "computer scientists predict that within the next twenty years neural interfaces will be designed that will not only increase the dynamic range of senses, but will also enhance memory and enable "cyberthink" — invisible communication with others." [quoted from <http://www.bu.edu/wcp/Papers/Bioe/BioeMcGe.htm>, 4 April 1999, accessed on 18 October 2004]

✚ Prosthetic cortical implant (intelligence or sensory "amplifiers")

The user's visual cortex will receive stimulation from a computer based either on what a camera sees or based on an artificial "window" interface.

✚ Audio tooth implant or tooth phone

Described in 2002, the Audio tooth implant, designed by James Auger, still only exists in concept form.

A micro-vibration device and a wireless low frequency receiver are implanted in the tooth during routine dental surgery. The tooth communicates with an array of digital devices, such as mobile telephones, radio and computers.

Sound information is transferred from the tooth into the inner ear by bone transduction. Sound reception is totally discreet enabling information to be received anywhere at anytime.

<http://www.scienceandsociety.co.uk/results.asp?image=10328750&wwwflag=&imagepos=2>

. Accessed on 26 November 2004

Artificial hippocampus: as mentioned above, this implantable brain chip could enhance memory.